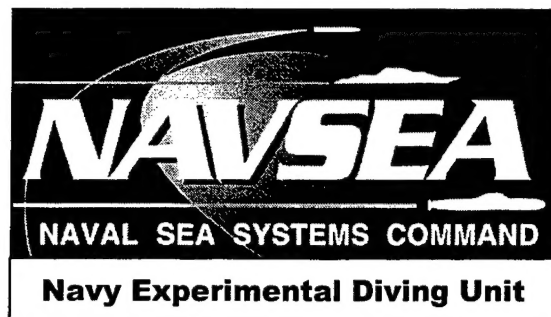


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**EVALUATION OF ZEAGLE
"RANGER" BUOYANCY
COMPENSATOR**

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19. ABSTRACT: NEDU was tasked to conduct a survey of commercially available buoyancy compensators (BCs), and perform testing to determine which BC perform satisfactorily. Buoyancy compensator evaluation was conducted in three phases. Phase I, receipt inspection of the buoyancy compensator, technical review of the manufacturer supplied documentation (instructions / repair manuals), diver orientation, and Test Pool Evaluation (BC surface floating attitudes if used as a Life Jacket). No failure mode analysis was conducted. Phase II consisted of buoyancy / lift capacity testing in the OSF at 190 fsw. Phase III consisted of manned dives in the Gulf of Mexico to test diver buoyancy control and operational characteristics.				
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INTRODUCTION

Navy Experimental Diving Unit (NEDU) is tasked¹ to conduct surveys of commercially available buoyancy compensators (BCs), and perform testing to determine which BCs perform satisfactorily in accordance with references (2) and (3). All buoyancy compensators that meet the above requirements will be candidates for recommendation to the Authorized for Navy Use (ANU) list. The purpose of this technical report is to determine if Zeagle "Ranger" buoyancy compensator meets those requirements.

METHODS

GENERAL

Each BC was tested and evaluated in three different environments Phase I (Bench Test), Phase II (Controlled Environment (Test Pool/Ocean Simulation Facility (OSF))), and Phase III (Open Ocean Diving). While bench testing, each BC was evaluated by two qualified U.S. Navy divers for completeness and adequacy of maintenance manuals and technical documentation, skill level required to perform routine repair and maintenance, operation of the integrated weight belt and the operation of all BC components. In a controlled environment, each BC was tested and evaluated for buoyancy and lift capability. While performing open water dives, each BC was used and evaluated by ten qualified U.S. Navy divers in both single and double SCUBA tank configurations to a minimum of 30 fsw (9.4 msw). The conversion for msw is in accordance with reference (4).

EXPERIMENTAL DESIGN AND ANALYSIS

All BCs tested were off the shelf items; three sizes were tested, (i.e., medium, large and X-large). The Task Leader or assigned representative was present during the set-up and post-dive procedures on all BCs.

Phase I testing:

- Each model BC was evaluated by two qualified U.S. Navy divers for ease of operation and maintenance procedures.
- Average cost, from five different suppliers was acquired.

Specific comments from evaluators were compiled and documented.

Phase II testing:

- All different size BCs were tested to 190 fsw (59.4 msw) utilizing the OSF. Each BC was fully inflated three times in both single and twin configurations, recording the average lift capacity.

Phase III testing:

- Each different size BC were evaluated during open water dives. A series of evaluation dives consisted of ten man-dives per BC, per tank configuration

(i.e., single, twin). All open water dives were conducted to a minimum depth of 30 fsw. Divers completed a human factor questionnaire after each dive. A set of descriptive statistics of the responses and specific comments were compiled.

EQUIPMENT AND INSTRUMENTATION

No special or proprietary tools were required to perform routine maintenance or repair on the BCs.

- a. Phase I: During bench testing, the following equipment was used:
 - (1) Fully charged SCUBA bottle and an approved regulator
(used to supply low-pressure air to perform equipment checks)
 - (2) Manufacturer's instructions and maintenance manual
 - (3) Miscellaneous hand tools and adapter fittings
 - (4) Weights (soft or molded)
- b. Phase II: During OSF testing the following equipment was used:
 - (1) Calibrated Viking spring scale model 895, 0 to 50 pounds (0 to 22.7 kg)
manufactured by Hanson in Shubuta, Mississippi.
 - (2) Lanyards, spinnaker shackles, and weight as appropriate to anchor BCs to
deck in wet chamber
 - (3) Fully charged SCUBA bottle and an approved regulator (used to supply
low-pressure air)
 - (4) Personnel as required
 - (5) Weights
- c. Phase III: During at sea testing, the following equipment was used:
 - (1) Fully charged SCUBA bottle, approved regulator and all other personnel diving
equipment needed to perform a SCUBA dive
 - (2) Personnel as required
 - (3) At sea diving platform

PROCEDURES

BC evaluation was conducted in three phases: (1) receipt inspection and technical review of manufacturer supplied documentation, (2) OSF wet chamber evaluation (buoyancy/lift capacity at 190 fsw) and (3) open water dives to test buoyancy control and operational characteristics.

- a. Phase I testing began with a review of the following:
 - (1) Completeness and adequacy of the maintenance manuals and technical
documentation
 - (2) Requirements for special or proprietary tools
 - (3) Skill level required to perform routine repair and maintenance
 - (4) Operation of integrated weight system

- (5) Operation and activation of all BC components
- (6) Ease of assembly from single tank configuration to twin tank configuration
- (7) Unit price

A technical documentation and operational function worksheet was completed by each qualified diver assigned, and returned to the Task Leader.

b. Phase II Testing: Buoyancy/lift capacity of the units were tested in the OSF wet chamber at depths of 190 fsw. All divers participating in the study were required to familiarize themselves with the contents of the user's manual, to include location of controls on the BC and donning procedures.

A calibrated Viking spring scale model 895 was attached to the deck grating of the OSF to measure buoyancy. Each BC tested was attached to the scale and tested in the OSF pressurized to 190 fsw. The buoyancy was measured and documented; at a minimum, each BC was required to provide 10 lbs. of positive lift as outlined in reference (3). The BC was also tested for leaks at depth.

c. Phase III Testing: Manned open water dives were conducted to a minimum depth of 30 fsw to determine each BC's swim characteristics. Results were documented using a diver's questionnaire.

RESULTS

PHASE I

The inspection of the manufacturer's supplied documentation on the use, service, parts, technical aspects and exploded views/diagrams was unsatisfactory. Documentation also failed to include a parts list or technical specifications within the supplied buoyancy compensator manual, but are available from the manufacturer upon request. There were no requirements for special or proprietary tools needed. Skill level required to perform routine maintenance should be at least a second class diver or above. The integrated weight system weights were secure and easy to operate the release mechanism, even though the weights were difficult to reinstall for redeployment. The operation and activation of all BC components were easy to operate. There were no problems assembling the single tank configuration to the twin tank configuration.

The average manufacturer's suggested price per unit (X-Small – X-Large) is \$338.25.

PHASE II

The average of all sizes of the "Ranger" in the single tank configuration was 31.3 lbf of positive lift at 190 fsw (see Table 1). The measured buoyancy of the "Ranger" BC was

approximately 28.7% less than the 44 lbf (all bladder sizes are listed as 44 lbf.) quoted by the manufacturer. However, that difference might have been due to differing test conditions, procedures, or depth.

In the twin tank configuration, the three sizes of the "Ranger" averaged 30.8 lbf of positive lift at 190 fsw (see Table 1). The measured buoyancy of the "Ranger" BC was approximately 30% less than the 44 lbf (all bladder sizes are listed as 44 lbf.) quoted by the manufacturer. Again the difference might have been due to differing test conditions, procedures, or depth.

PHASE III

During the manned evaluation of the Zeagle "Ranger," 20 divers tested the buoyancy compensator in both tank configurations to depths ranging from 30 to 130 fsw. On a scale of 1 – 7 (4.0 being the minimum mark for an overall acceptable score), this BC scored a rating of 4.74 in the single tank configuration and 5.21 in the twin tank configuration. The BC "Ranger" has an integrated weight belt system that can be removed and ditched from the buoyancy compensator by the diver in case of emergency⁴. This system is easy to use and easy to reinstall onto the buoyancy compensator. The weight module pockets are designed to hold a maximum of 20 lbs. of molded or soft weights in each pocket for a total onboard weight capacity of 40 lbs.

CONCLUSIONS

While testing this BC, three major items of concern were encountered through divers comments and operation; 1) Locating the LP inflator and the rear lower dump valve was difficult. 2) The single tank configuration scored 17% lower and had more negative comments than the twin tank configuration. Over 60% of the divers felt that the single tank configuration would not be an asset to the fleet in comparison to the twin tank configuration. 3) While diving it was observed that the diver's tank would slip down. Although it is not listed in the manufacturer's technical manual, prior to each diving day PMS MIP 5921/023 R-1 must be completed. Wetting the straps did correct the problem. If this is not completed, the bottle could slip down and out of the BC which could lead to the loss of the diver's air supply.

RECOMMENDATIONS

Based on the testing and evaluation in accordance with reference (3) and reported in Tables (1) and (2), we recommend that the Zeagle Model name "Ranger" (P/N: 7908RKM (size) Extra Small, Small, Medium, Large, X-Large) be authorized for continued Navy use. Prior to each diving day PMS MIP 5921/023 R-1 must be completed. No surface floating attitude testing was conducted; as per manufacturer supplied documentation the use of this BC, therefore we do not recommend this buoyancy compensator to be used as a life preserver.

Table 1. Zeagel "Ranger" Buoyancy Compensator Pull Test Data Sheet

Zeagel "Ranger" Single Tank Configuration					
NO.	NOMENCLATURE	BC SIZE	BUOYANCY (LBF)	DEPTH	INFLATION METHOD
1	Zeagel "Ranger"	M	30	190 FSW	LP WHIP FROM SCUBA BOTTLE
2	Zeagel "Ranger"	L	32	190 FSW	LP WHIP FROM SCUBA BOTTLE
3	Zeagel "Ranger"	XL	32	190 FSW	LP WHIP FROM SCUBA BOTTLE
	Average Buoyancy		31.3		
Zeagel "Ranger" Double Tank Configuration					
NO.	NOMENCLATURE	BC SIZE	BUOYANCY (LBF)	DEPTH	INFLATION METHOD
1	Zeagel "Ranger"	M	29	190 FSW	LP WHIP FROM SCUBA BOTTLE
2	Zeagel "Ranger"	L	31	190 FSW	LP WHIP FROM SCUBA BOTTLE
3	Zeagel "Ranger"	XL	31	190 FSW	LP WHIP FROM SCUBA BOTTLE
	Average Buoyancy		30.8		

Table 1. Each size BC was tested to 190 fsw (59.4) utilizing the OSF. Each BC was fully inflated three times in both single and twin configurations. Recording the average lift capacity.

Table 2. Human Factors Evaluation of the Zeagle "Ranger" Bupyancy Compensator in Single and Twing Tank Configuration.

Zeagle "Ranger" Single Tank Configuration										
QUESTIONNAIRE #	#9	#10	#11	#12	#13	#14	#15	#16	#17	
	Comfort	Mobility	Donning & Doffing	Neutral Buoyancy Swimming	Neutral Buoyancy Standing	Neutral Buoyancy Supine	Neutral Buoyancy Prone	Integrated Weights	Tank Attachment	
1	4	5	5	5	5	5	5	4	5	
2	5	5	4	4	4	4	4	4	4	
3	3	3	6	5	5	6	6	5	6	
4	5	5	4	5	5	4	5	4	4	
5	5	4	4	2	2	2	2	5	5	
6	4	3	3	5	5	5	5	3	4	
7	4	4	5	5	5	5	5	5	6	
8	5	5	6	6	6	5	6	5	4	
9	6	5	6	6	6	6	6	6	6	
10	6	6	6	6	6	6	6	6	4	
QUESTION AVERAGE	4.70	4.50	4.90	4.90	4.90	4.90	4.90	4.80	4.90	
Zeagle "Ranger" Double Tank Configuration										
QUESTIONNAIRE #	#9	#10	#11	#12	#13	#14	#15	#16	#17	
	Comfort	Mobility	Donning & Doffing	Neutral Buoyancy Swimming	Neutral Buoyancy Standing	Neutral Buoyancy Supine	Neutral Buoyancy Prone	Integrated Weights	Tank Attachment	
1	6	6	6	6	6	6	6	6	4	
2	5	4	4	4	4	4	4	6	4	
3	6	5	6	6	6	6	5	6	6	
4	6	5	6	6	6	5	5	4	6	
5	6	6	6	5	6	6	6	6	6	
6	5	5	4	4	4	4	4	4	4	
7	6	6	6	6	6	6	6	6	6	
8	4	4	4	5	5	5	5	4	5	
9	6	6	4	6	6	6	6	7	4	
10	4	3	2	5	5	4	5	4	4	
QUESTION AVERAGE	5.40	5.00	4.80	5.30	5.40	5.20	5.20	5.30	4.90	

Table 2. A series of evaluation dives will consist of ten man dives per BC, per tank configuration. All open water dives were conducted at a minimum depth of 30 fsw (9.4 msw). Divers completed a human factors questionnaire after each dive. A set of descriptive statistics of the responses and specific comments were compiled. The BCs is scored on a scale of 1 – 7 scale (4.0 being the minimum mark for an overall acceptable score) (1 = poor, 4 = adequate, 7 = excellent).

Table 2 (cont.) Human Factors Evaluation of the Zeagle "Ranger" Bupyancy Compensator in Single and Twin Tank Configuration.

Zeagle "Ranger" Single Tank Configuration												
QUESTIONNAIRE #	#18		AVERAGE	#19		#20	#21	#22	#23	#24	#25	#26
	Over All Rating	Operating Controls		Wearing Gloves	Water Drag							
1	4	3	3.50			Y	Y	Y	N	N	N	N
2	4	5	4.50			Y	N	Y	N	Y	N	N
3	3	6	4.50			Y	Y	Y	N	N	N	N
4	5	3	4.00			Y	N	Y	Y	N	Y	Y
5	2	2	2.75			Y	N	N	Y	N	N	N
6	3	4	3.50			Y	Y	Y	Y	N	N	N
7	5	5	5.00			Y	Y	Y	N	Y	N	N
8	5	5	5.00			Y	Y	Y	N	Y	Y	Y
9	6	6	6.00			Y	N	Y	N	Y	Y	Y
10	8	8	8.00			Y	N	Y	Y	Y	Y	Y
QUESTION AVERAGE	4.30	4.50	4.48	10 out of 10 YES	5 out of 10 YES	9 out of 10 YES	4 out of 10 YES	5 out of 10 YES	4 out of 10 YES	4 out of 10 YES	4 out of 10 YES	4 out of 10 YES
Overall Average			4.48									
Zeagle "Ranger" Double Tank Configuration												
QUESTIONNAIRE #	#18		AVERAGE	#19		#20	#21	#22	#23	#24	#25	#26
	Over All Rating	Operating Controls		Wearing Gloves	Water Drag							
1	6	6	6.00			Y	N	Y	Y	Y	Y	Y
2	6	6	6.00			Y	N	Y	N	Y	Y	Y
3	6	6	6.00			Y	Y	Y	N	Y	Y	Y
4	6	6	6.00			Y	N	Y	N	Y	Y	Y
5	6	6	6.00			Y	Y	Y	N	Y	Y	Y
6	4	5	4.50			Y	N	N	N	Y	N	N
7	6	6	6.00			Y	Y	Y	N	Y	Y	Y
8	4	4	4.00			Y	Y	N	Y	N	N	N
9	6	6	6.00			Y	N	Y	N	Y	Y	Y
10	3	4	3.50			Y	N	Y	Y	Y	N	N
QUESTION AVERAGE	5.30	5.50	5.40	10 out of 10 YES	4 out of 10 YES	8 out of 10 YES	3 out of 10 YES	9 out of 10 YES	7 out of 10 YES	7 out of 10 YES	7 out of 10 YES	7 out of 10 YES
Overall Average			5.40									

Table 2. A series of evaluation dives will consist of ten man dives per BC, per tank configuration. All open water dives were conducted at a minimum depth of 30 fsw (9.4 msw). Divers completed a human factors questionnaire after each dive. A set of descriptive statistics of the responses and specific comments were compiled. The BCs is scored on a scale of 1 – 7 scale (4.0 being the minimum mark for an overall acceptable score) (1 = poor, 4 = adequate, 7 = excellent).

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1. Commander, Naval Sea Systems Command, Task Assignment 98-10, *Commercial Diving Equipment Test and Evaluation*, Dec 97.
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4. Naval Sea Systems Command, *U.S. Navy Diving Manual*, Vol. #5, Rev. 4, NAVSEA SS521-AG-PRO-010, 20 Jan 99, Ch. 7-2.3.4, pp. 7-9.